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● *Original Contribution*

DOES B-MODE COMMON CAROTID ARTERY INTIMA-MEDIA THICKNESS DIFFER FROM M-MODE?

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Abstract—An increased intima-media thickness of the common carotid artery is thought to be an early sign of atherosclerosis. Both B- and M-mode ultrasonographic techniques are used to measure the intima-media thickness of the common carotid artery (B-IMT and M-IMT, respectively). The present study compares intima-media thickness of the common carotid artery measured with the two techniques. Intima-media thickness was measured in a random population sample of 250 subjects. Comparison was made by mean and 95% confidence intervals of differences between B-IMT and M-IMT, by linear regression analysis, and by intraclass and concordance correlation coefficients. M-IMT was + 0.011 ± 0.091 mm (95% confidence intervals: −0.167 to + 0.188 mm) larger than B-IMT, which was 0.661 ± 0.136 mm (range: 0.380 to 1.120 mm). Intraclass and concordance correlation coefficients were 0.802 and 0.801, respectively. In conclusion, acceptable agreement exists between the two methods and there was no important systematic difference between B-IMT and M-IMT. (E-mail: luc.vanbortel@rug.ac.be) © 2001 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Intima-media thickness, B-mode, M-mode, Arterial wall, Common carotid artery, Atherosclerosis, Diagnostic imaging.**

INTRODUCTION

Intimal thickening at the carotid artery has been suggested as an early stage of atherosclerotic disease (Stary et al. 1992). *In vivo*, intimal thickening cannot be measured noninvasively. Intima-media thickness (IMT) can be measured with ultrasound (US). An increased IMT can be due to intimal and/or muscular thickening (Grobbee and Bots 1994). At the common carotid artery (CCA), an increased IMT has been found associated with clinically manifest disease (Burke et al. 1995; Salonen and Salonen 1991). As a consequence, at the site of the CCA, IMT is considered mainly due to intimal thickening (Grobbee and Bots 1994), and has been proposed as a surrogate for intimal thickening at this arterial site.

The ultrasonographic measurements of carotid artery IMT have acceptable accuracy (Girerd et al. 1994; Hoeks et al. 1997; Persson et al. 1994; Pignoli et al. 1986; Wendelhag et al. 1991; Wong et al. 1993) and are reproducible (Mountauban van Swijndregt et al. 1999; Smilde et al. 1997; Stensland-Bugge et al. 1997; Willekes et al. 1999), especially when applied in large multinational clinical trials (Kanters et al. 1998; Tang et al. 2000). Its noninvasive character and easy applicability make ultrasonography a powerful tool for assessment of early atherosclerotic vessel wall changes, even in asymptomatic patients where the artery lumen is not yet obstructed (Crouse and Thompson 1993; Probstfield et al. 1995). IMT can be measured in different segments of the carotid artery, such as the common carotid artery, bulbus, and internal carotid artery, but reproducibility is higher in the common carotid artery (CCA) segment (Mountauban van Swijndregt et al. 1999).

Different US techniques have been used to measure the IMT of the CCA. One technique, using high-resolution B-mode images, was proposed by Bond and Ball (1986) and Pignoli et al. (1986) and further elaborated by Wendelhag et al. (1991). In this 2-D US image of the CCA, the anterior wall, the lumen and the posterior wall

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Table 1. Subjects' characteristics

Demographic data ($n = 250$)	
Male/female	118/132
Age (years)	50 ± 13
BMI (kg/m^2)	26 ± 4
Smokers	85
SBP (mmHg)	120 ± 14
DBP (mmHg)	72 ± 9

BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; data are number or mean ± SD.

can be distinguished. Both walls present 1. an echogenic, 2. an echo-poor, and 3. an echogenic zone. IMT of the far wall is measured, whereas that of the near wall is not considered because measurements of the line pattern at the near wall have to be performed at the trailing edges of the US pulse and are, therefore, not representative of IMT. As a result, these measurements depend on gain settings and resolution characteristics of the US device, and represent only 80% of the histologic thickness (Wong et al. 1993). In the far wall, the interface between lumen and intima gives rise to the leading edge of the first echogenic zone. The leading edge of the second echogenic zone in this wall very likely corresponds to the media-adventitia interface (Pignoli et al. 1986). The distance between these two leading edges is taken as IMT (Pignoli et al. 1986), and truly reflects the anatomical IMT (Pignoli et al. 1986; Wendelhag et al. 1991).

Another technique, using M-mode images, has been proposed by Roman et al. (1992). Two-dimensionally guided M-mode tracings of the common carotid artery are performed and stored for off-line analysis. Following calibration for depth and time, the end-diastolic wall thickness of the far wall is measured. In contrast to B-mode IMT, which represents the average IMT of an arterial segment, M-mode IMT is the IMT at a discrete arterial position.

Because studies comparing the two techniques are lacking, it is not clear if these two techniques produce similar results. The present study compares the results of IMT of the CCA measured with these two techniques in 250 subjects from a random population sample.

MATERIALS AND METHODS

Subjects

The subjects' characteristics are presented in Table 1. Subjects were part of a random population sample (van der Heijden-Spek et al. 2000). They were from 27 to 82 years old; the majority were older than 50 years. Their body mass index (BMI) ranged from 16 to 45 kg/m^2. The study was approved by the local ethics committee and written informed consent was obtained from all subjects.

Carotid ultrasonography

Ultrasonography of the right CCA was performed in all subjects, using a conventional echo-imaging system (Ultramark V, ATL, Bothel, WA) equipped with a 7.5-MHz linear-array transducer. After 15 min of supine rest, subjects were examined with the head turned 45° opposite to the site being scanned. Registrations in B-mode and M-mode of the far wall were made consecutively at 1 cm proximal to the bulb, without displacing the transducer. An optimal 2-D image in B-mode was obtained and images were continuously recorded on videotape. To obtain M-mode images, an M-line perpendicular to the vessel was selected in an optimal B-mode image and the US system was switched to M-mode. M-mode images were also continuously recorded on videotape. A simultaneously recorded electrocardiogram was used to maintain a constant time relationship between the IMT measurements and the cardiac cycle. All measurements were performed by one investigator.

Image analysis

Evaluable frozen end-diastolic B-mode images on the videotape were digitized, stored on disc and analyzed off-line using a computerized image-analyzing system. This procedure has been described in detail by Wendelhag et al. (1991). Briefly, with a cursor the interfaces of the far wall of the CCA were traced manually over a length of at least 6 mm. IMT is calculated automatically by the computer by dividing the area of the intima-media complex by the length of the arterial segment. Six B-mode images were analyzed and the mean of four registrations after exclusion of the highest and lowest value was calculated.

Suitable frozen end-diastolic M-mode images on the videotape were analyzed off-line using a computerized system with an image-shearing device that was built in our institute, according to the description of Intaglietta and Tompkins (1973). Following calibration for depth, the end-diastolic IMT was measured. Eight M-mode images were analyzed and the mean of six registrations after exclusion of the highest and lowest value was obtained. B-mode and M-mode images were analysed by one reader. In our hands, the intrasession and intersession coefficients of variation of these image analyses were 2.9% and 5.3% for B-mode IMT (B-IMT) and 1.4% and 5.4% for M-mode IMT (M-IMT), respectively.

Statistical analysis

Data are presented as mean ± SD. Comparison of the two techniques was made by: 1. mean and 95% confidence intervals (CI) of differences between B-IMT and M-IMT according to Bland and Altman (1986); 2. intraclass (ICC) and concordance (CCC) correlation coefficients according to Deyo et al. (1991); and 3. linear

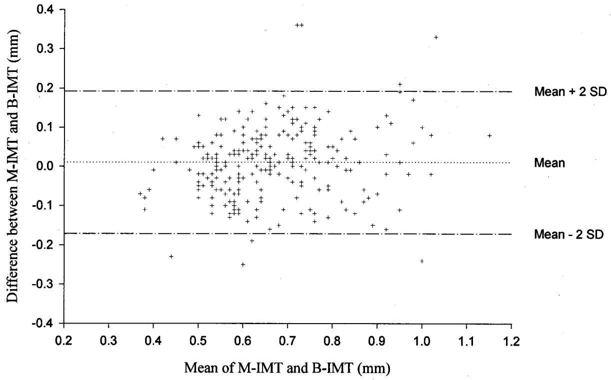

Fig. 1. Agreement between intima-media thickness measured with M-mode and with B-mode. Bland and Altman scatterplot (n = 250); M-IMT and B-IMT = intima-media thickness measured with M-mode and with B-mode, respectively. Lines are drawn for the mean difference and 2 SD around the mean difference.

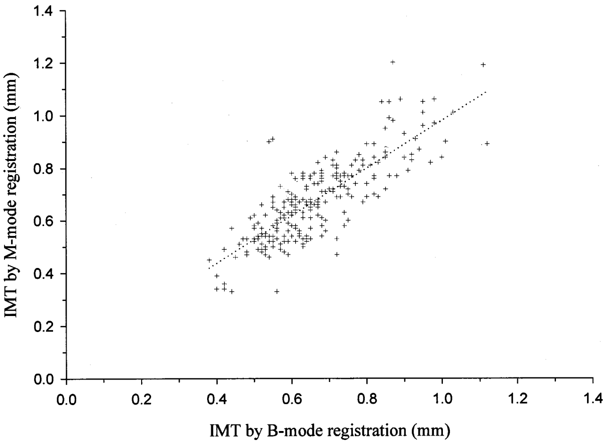

Fig. 2. Regression line of relation between M-IMT and B-IMT. M-IMT and B-IMT = intima-media thickness measured with M-mode and with B-mode, respectively.

regression analysis and Pearson (r) correlation coefficient. ICC reflects 1. overall correlation; 2. systematic difference; and 3. agreement with the 45° line of identity. The concordance correlation coefficient (CCC) reflects the agreement between the observed data and a 45° line of identity (Lin 1989).

RESULTS

B-IMT and M-IMT in the study population averaged 0.661 ± 0.136 mm (range: 0.380 to 1.120 mm) and 0.672 ± 0.152 mm (range: 0.328 to 1.197 mm), respectively. The mean difference between M-IMT and B-IMT (M-IMT minus B-IMT) and its SD was 0.011 ± 0.091 mm (95% CI −0.167 mm to 0.188 mm) (Fig. 1). ICC and CCC were 0.802 and 0.801, respectively. Pearson (r) was 0.808 in the linear regression analysis ($y = 0.906x + 0.073$; Fig. 2). Using this linear regression model, B-IMT and M-IMT were calculated as identical at IMT = 0.779 mm.

DISCUSSION

Agreement between the two methods was acceptable as evidenced by: 1. limited deviation from the line of identity (CCC ≥ 0.8 and almost identical to ICC); 2. no important systematic difference between B-IMT and M-IMT (mean difference close to 0 and ICC almost identical to r); and 3. an acceptable overall correlation (ICC ≥ 0.8 and 95% CI of differences).

The measurement of the combined thickness of the intima and media (the intima-media thickness) of arteries and of the CCA in particular is widely applied. IMT of the common carotid artery has been used in population-based epidemiologic studies (Burke et al. 1995; Gariepy et al. 1995; Grobbee and Bots 1994; Salonen and Salonen 1991), and is advocated and used as intermediate endpoint in clinical trials for the assessment of the middle- and long-term effects of treatment on progression or regression of atherosclerosis (Blankenhorn et al. 1993; Bond and Mercuri 1995; Borhani et al. 1986; Crouse et al. 1995; De Groot et al. 1995; Furberg et al. 1994; Mercuri et al. 1996; Westendorp et al. 1999). Local IMT, as a surrogate for wall thickness, is also required to assess arterial wall properties (*e.g.*, the Young's modulus) (Joannides et al. 1997).

The large majority of studies on IMT used B-mode. Should B-mode be used in clinical practice rather than M-mode? The B-mode and M-mode methods both have their own advantages and disadvantages. B-IMT is the average IMT along a continuous arterial segment, and M-IMT measures only the IMT at one discrete position. As a consequence, differences between the two methods in the present study can, at least in part, be due to inhomogeneities of the arterial wall. The B-mode analysis is complicated by the speckle pattern and preprocessing of the video images (Easton et al. 1994). Averaging will reduce the influence of speckle on IMT measurements (Hoeks et al. 1997). The B-mode off-line analysis was shown to be more complex and time-consuming than the M-mode off-line analysis if no automated computerized calculation program is available.

In conclusion, there is no important systematic difference between B-IMT and M-IMT. There is acceptable agreement between the two methods. At values of B-IMT < 0.779 mm M-IMT tended to be higher and at values of B-IMT > 0.779 mm it tended to be lower, but this deviation from the line of identity is small and acceptable.

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